The Lunar Surface-Atmosphere Interaction and Its Effect on Atmospheric Distribution

Dana M. Hurley

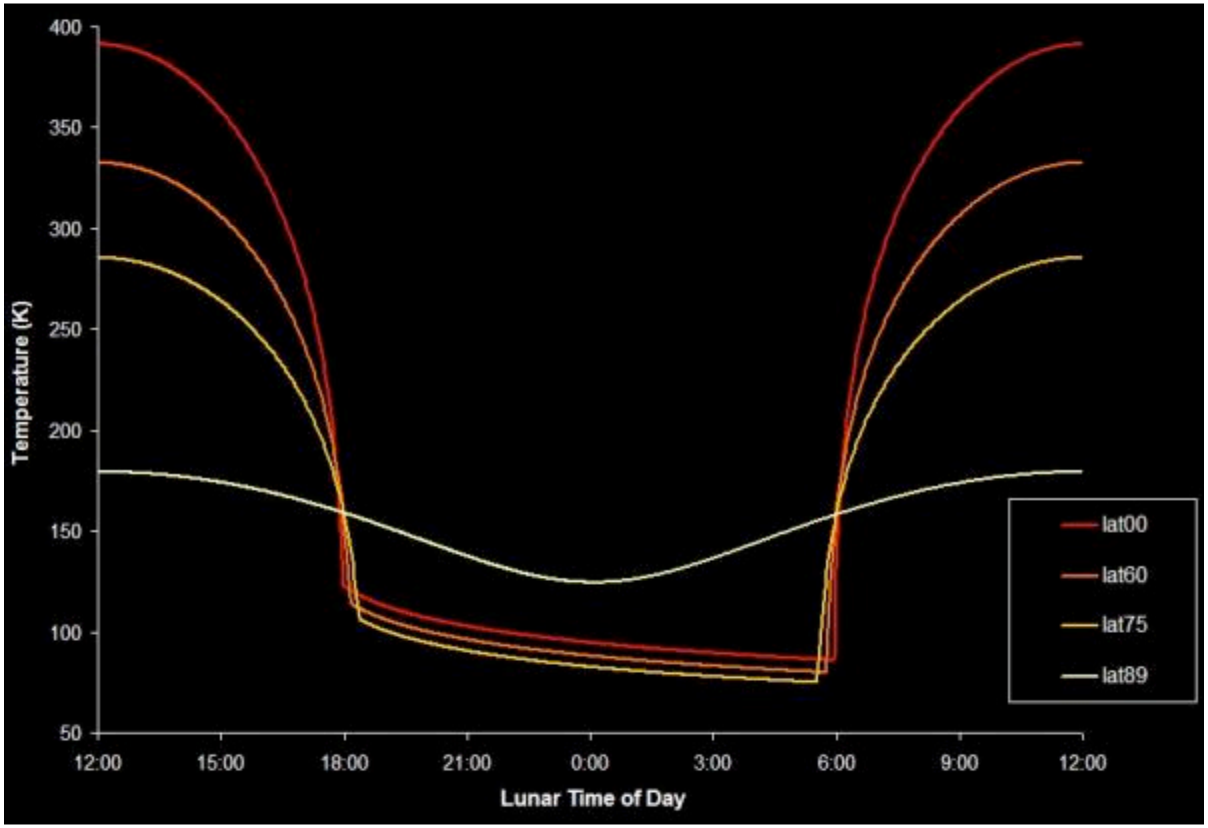
NASA LUNAR SCIENCE INSTITUTE

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

Key factors in determining the lunar atmospheric distribution

1. Temperature

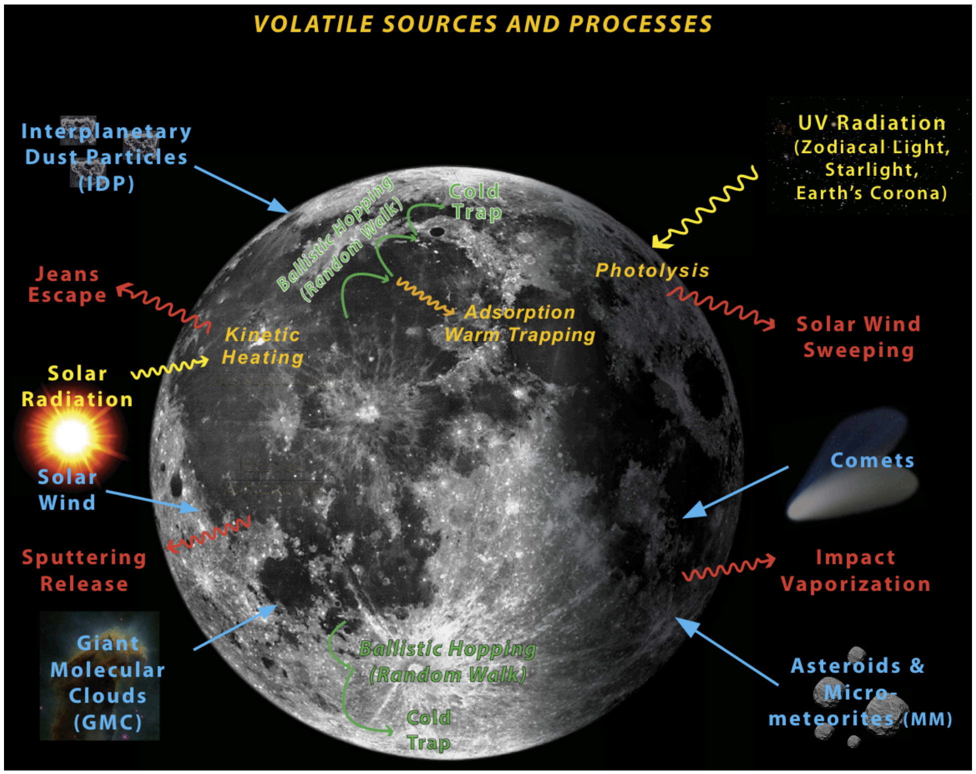
- Atmospheric density increases with decreasing temperature.
- Lunar surface temperature decreases with solar zenith angle
- Atmosphere would have peak density on the nightside and minimum density at the subsolar point



Diviner

Key factors in determining the lunar atmospheric distribution

2. Source distribution



- Lunar exosphere is transient
  - Lifetimes of particles from hours to days
  - Particles make ~100 hops
  - Constant competition between source and loss processes
- Lunar exosphere originates at the surface
  - Outgassing, sputtering, vaporization, desorption release processes all act near the surface

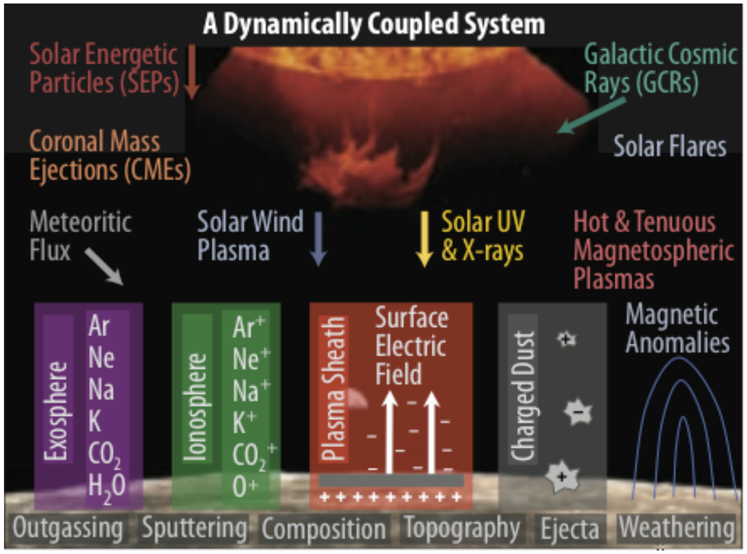
APL

Key factors in determining the lunar atmospheric distribution

3. Surface encounters

- The surface is the exobase
  - Interactions among “airborne” particles are unlikely
  - Interactions with surface grains are most likely
- Adsorption
  - Active sites
  - Temporary cold traps
  - Permanent cold traps
- Re-release
  - Bounce elastically
  - Thermally accommodate
  - Partial accommodation
  - Inelastic bouncing

The lunar surface/atmosphere interface is a crucial part of the lunar atmosphere.

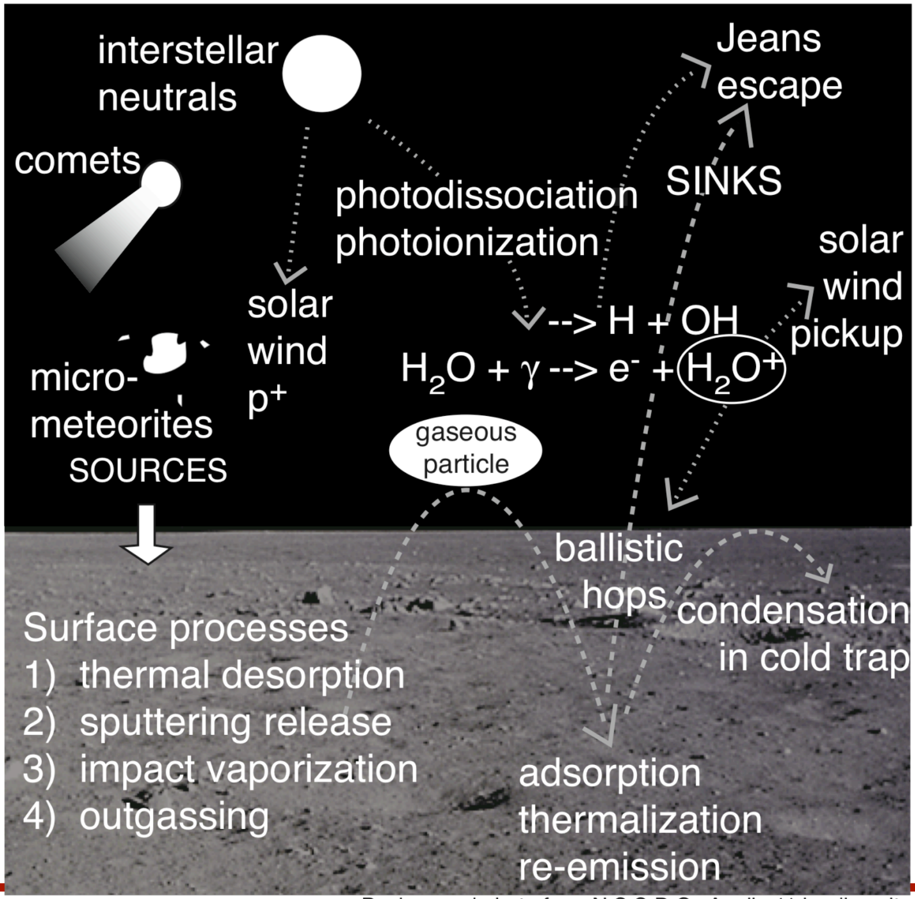


DREAM

APL

Monte Carlo Atmosphere Model

- Follows large number of particles from emission in atmosphere to eventual loss from system



Background photo from N.S.S.D.C., Apollo 11 landing site

- Species (so far)
  - H, H_2, He, OH, H_2O, Na, Ar
- Release mechanism
  - Position and velocity
- Surface interaction
  - Rerelease velocity
- Trajectory calculation
  - Gravity
  - Radiation pressure
- Loss processes

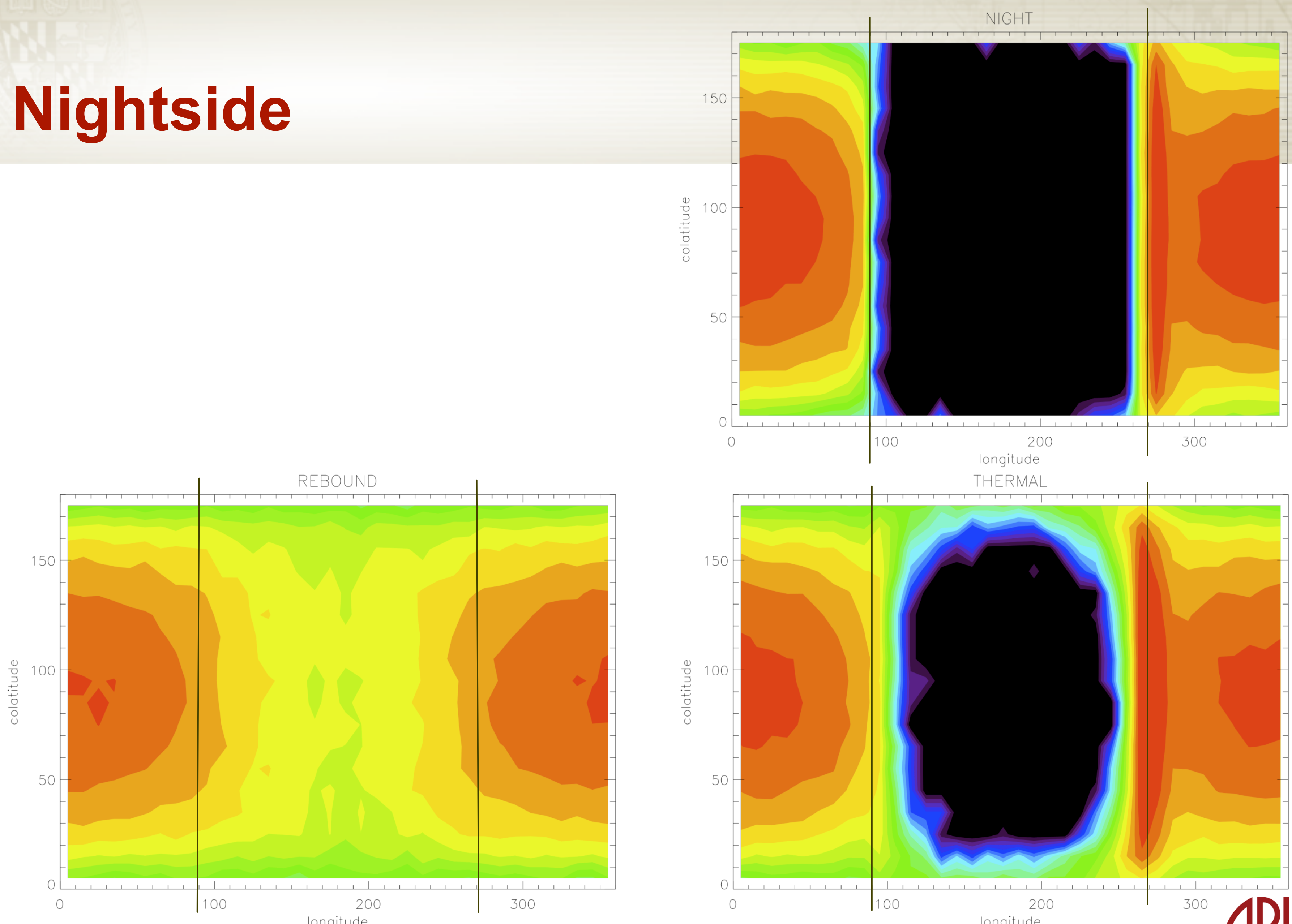
Uses of a Monte Carlo Atmosphere Model

- Developed with Rich Vondrak and Rosemary Killen
- The Monte Carlo exosphere model can be:
  - Used to study the effects of different physical processes on atmospheric composition and distribution
  - Paired with upcoming observations to provide insight into planetary surface, atmosphere, and plasma interactions
  - Applied to various bodies (Moon, Mercury)
- Improvements are ongoing
- Requests are welcome

Investigation of sodium and sticking

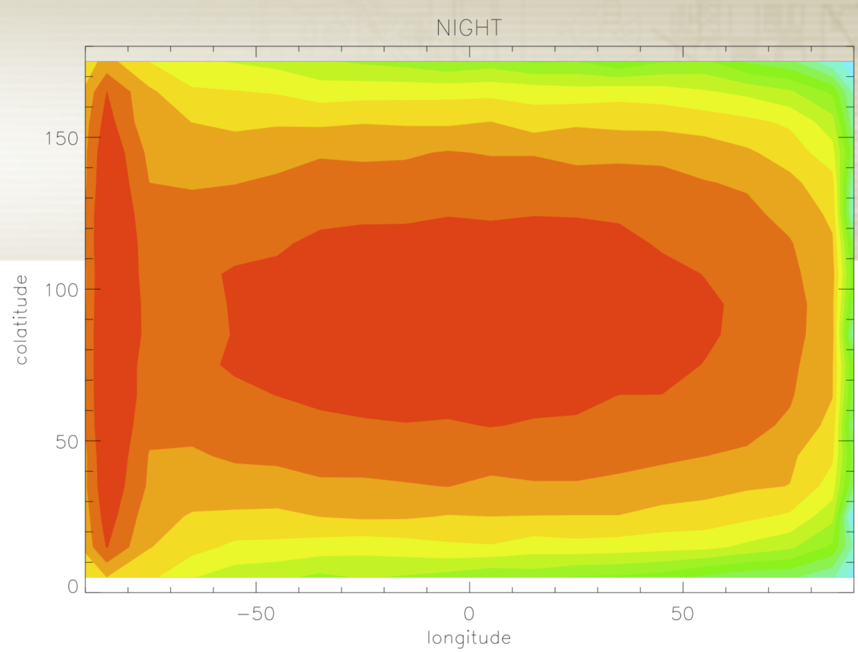
- **Assume a photon-stimulated desorption source**
- **Include radiation pressure**
- **Try 3 cases of surface interactions:**
  - **REBOUND: particle is reemitted with the same velocity it had when it encountered the surface**
  - **THERMAL: particle is reemitted with a velocity selected from the distribution associated with the local surface temperature**
  - **NIGHT STICKING: particles hitting the night side adsorb until they reach dawn, where they are reemitted with a thermal velocity**
- **Plot scale is in *log*(N/latitude/longitude)**

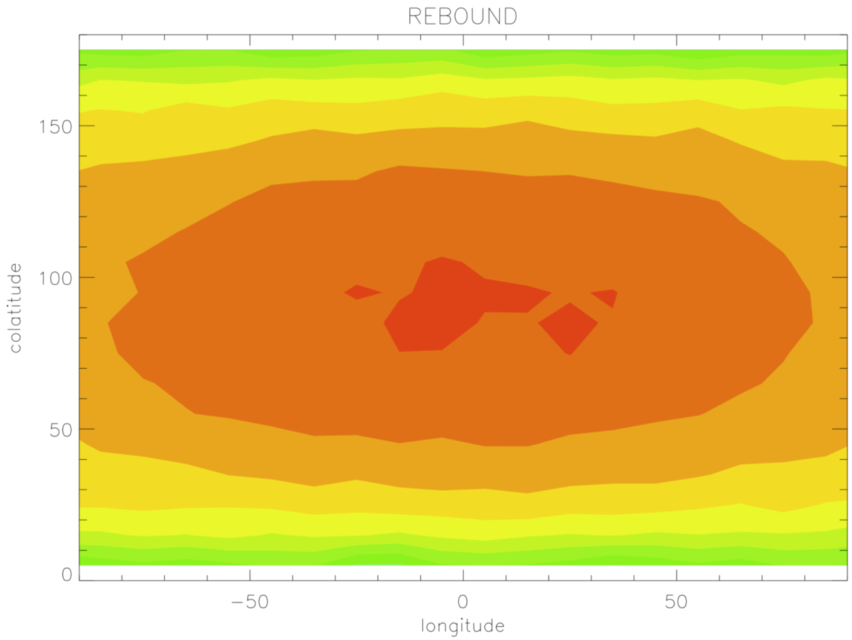
Nightside

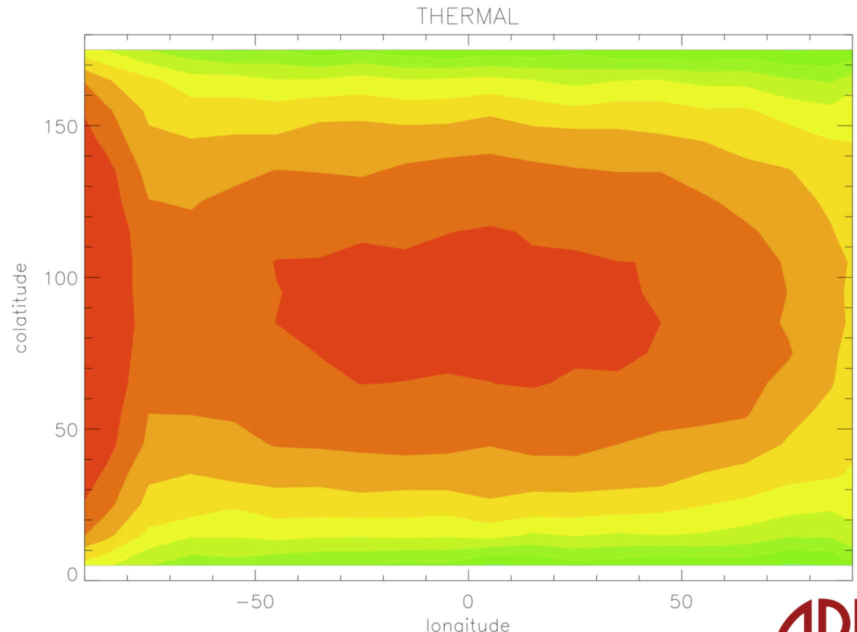


NIGHT
REBOUND
THERMAL
colatitude
longitude
0
50
100
150
200
300

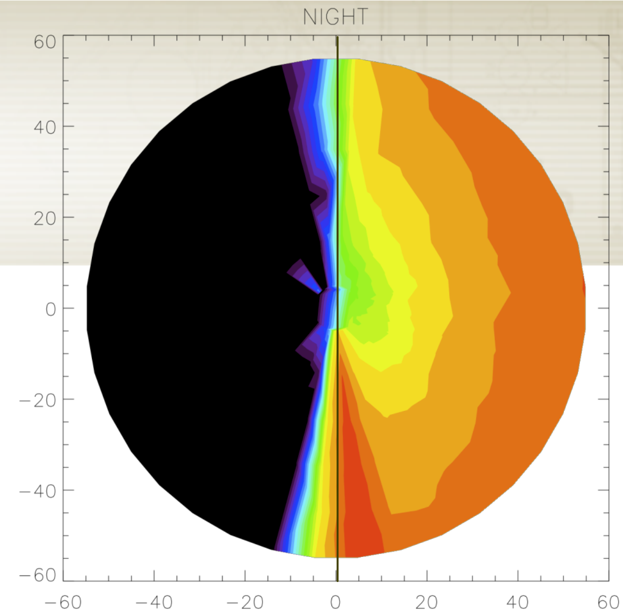
Dayside

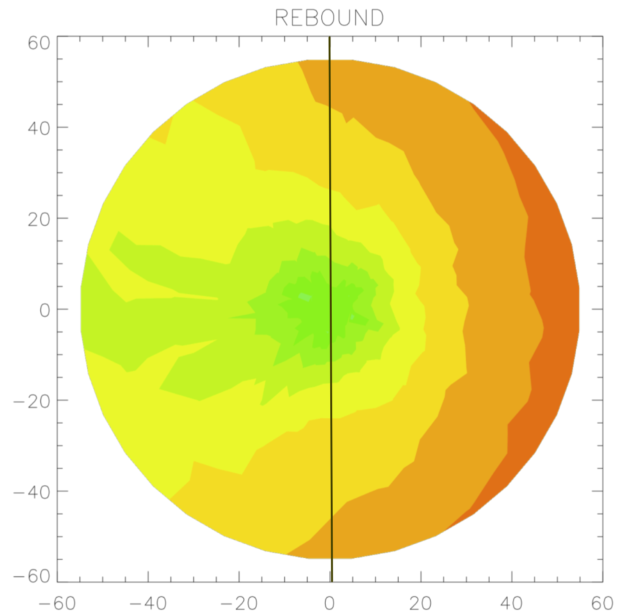

NIGHT
150
100
50
0
colatitude
−50
0
50
longitude

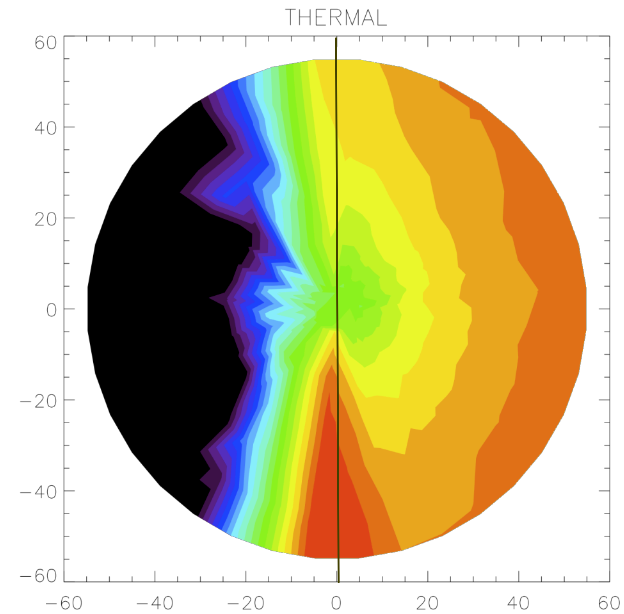

REBOUND
150
100
50
0
colatitude
−50
0
50
longitude


THERMAL
150
100
50
0
colatitude
−50
0
50
longitude

Polar view


NIGHT
60
40
20
0
−20
−40
−60
−60 −40 −20 0 20 40 60


REBOUND
60
40
20
0
−20
−40
−60
−60 −40 −20 0 20 40 60


THERMAL
60
40
20
0
−20
−40
−60
−60 −40 −20 0 20 40 60

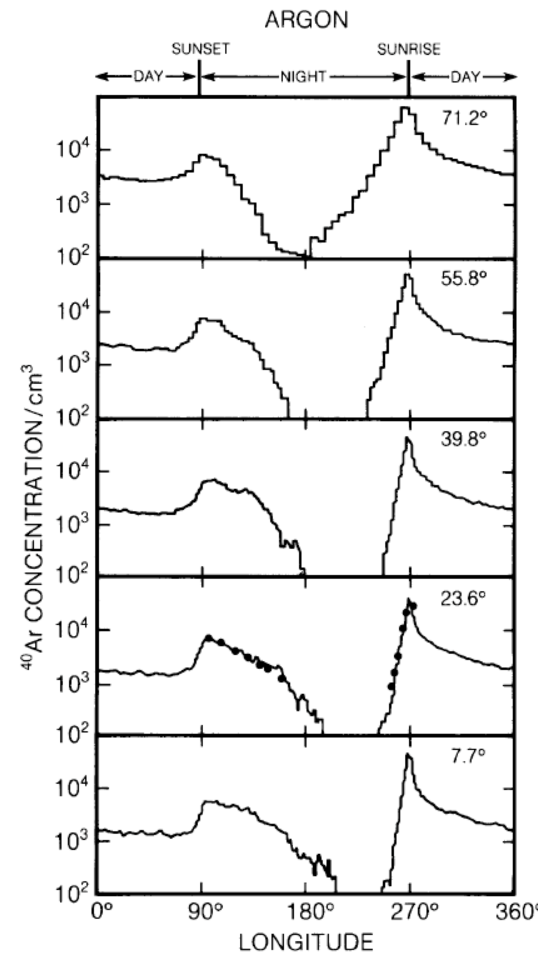
Conclusions

- Rebounding particles fill in the nightside atmosphere faster than thermalizing particles
- Thermalizing particles extend farther beyond the terminator than adsorbing particles
- Total atmospheric contents are similar for each case
- Dayside density for rebounding particles is lowest dayside density for these cases
- Competition between source rate, transportation time, and loss rate affect nightside density
- A dawn enhancement is readily apparent when the night surface acts as a sink

APL

What happens when an atmospheric particle encounters the surface?

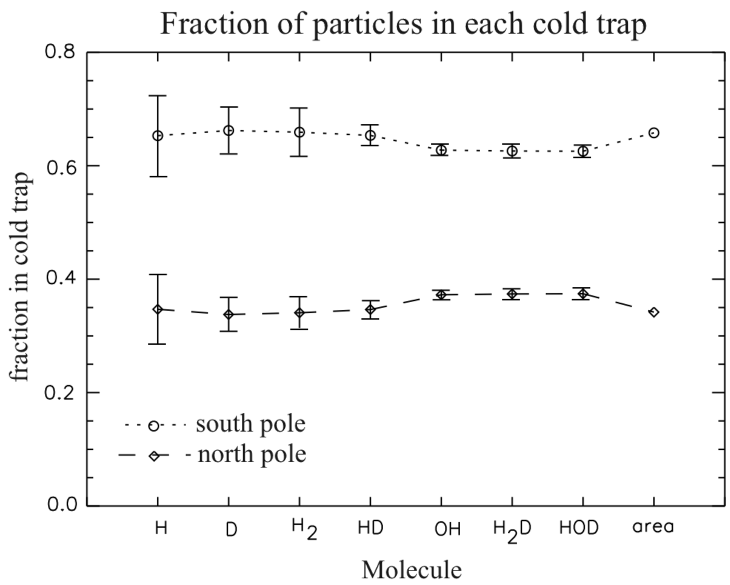
- When particles stick on the nightside, particles that are driven across the dawn terminator to the nightside are re-released at dawn in several hours.
- In contrast, the particles that are driven across the evening terminator stick to the nightside for the long lunar night and are re-released at dawn.
- Thus, the peak atmospheric density occurs at dawn.
- There is an asymmetry between dawn and dusk that depends on the efficiency of sticking and the re-release mechanism.



R. Hodges

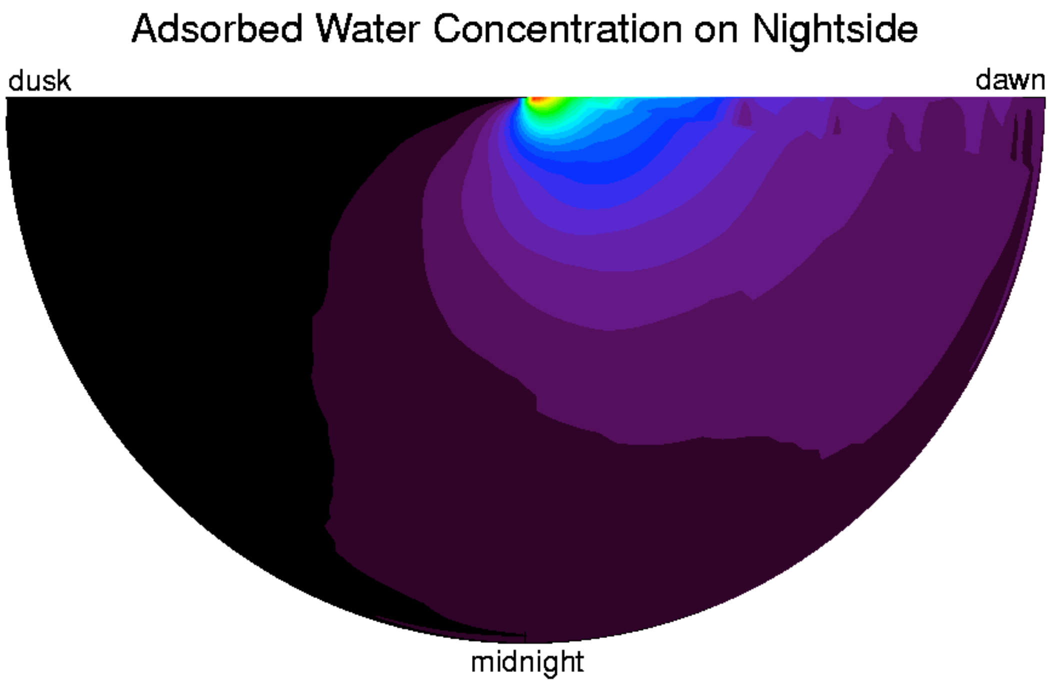
How does cold trap size affect atmospheric distribution?

- **A greater fraction of migrating particles condense in a larger cold trap, almost in proportion to the area.**
- **The Margot et al. [1999] estimate of total area in lunar shadow is smaller than the Bussey et al. [2003] estimate. Particularly, there is a great difference in the estimates for the PSR area in the northern hemisphere, where Bussey's estimate is 3x Margot's. For a small northern polar cold trap, there is more material in the atmosphere at high northern latitude than for a larger northern polar cold trap.**



What volatiles do we expect to be adsorbed to the nightside?

- This shows the adsorbed nightside concentration of water vapor from our model.
- Spatial distribution of loss processes, which can feed additional source processes



How does release distribution relate to final distribution?